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Moisture Characteristics As Affected By Land Use In A Typical Ultisol In A Humid Tropical Environment

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Abstract: *This study investigated the effect of land use on soil moisture characteristics of the ultisolsoils of Teaching and Research Farm of Rivers State University in the humid tropical environment of Rivers State Nigeria..Six (6) land uses were selected namely; Plantain plantation (PP), Orange orchard(OO), Mucuna (Mu), Maize plot (Mp) , Planted forest (Pf) and Telifera plot(Tp). The samples were collected at different depths (0-5, 5-10 and 10-20cm), the soil sample were subjected to various analysis using standard techniques. Undisturbed soil samples ere collected with 5x5cm cylindrical cores. These were used to determine bulk density, Total porosity, saturated hydraulic conductivity and soil moisture characteristics. Bulk samples were collected at same depths, air-dried and used for particle size, pH, organic carbon and nitrogen content determination.*
Results show that, texture of the soils was generally sandy loam to loamy sand. This lent to a high porosity: 36.9 t0 46%, 40.2 to 47.2%, and 40.6 to 43.6% for 05, 5-10 and 10-20 respectively. Saturated hydraulic conductivity ranged between 2.68cmhr^{-1} to 9.66cmhr^{-1} across all depths and land use. The planted forest had the lowest, bulk density of 1.43gcm^{-3}, highest porosity of 46% and saturated hydraulic conductivity of 9.62cmhr^{-1} and low moisture retention capacity. Orange orchard had the lowest saturated hydraulic conductivity of 2.68 cmhr^{-1} and maximum retention capacity of 4.22cm^{3}cm^{-3}, but the highest field capacity of 0.65cm^{3}cm^{-3}. Results suggest that physical properties were affected by land use and therefore hydraulic conductivity, moisture retention and availability.

Keywords: *Soil moisture characteristics, moisture retention, soil physical properties, land use*

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I. Introduction

Soil moisture characteristics, which gives the available moisture content as affected by the soil water potential energy is a determinant factor in the infiltration of water into the soil, retention of water and availability of soil water to plants. It is an important soil hydrological property, which is affected by soil structure, particle size distribution, land use systems, (Fu *et al.,* 2000), vegetation (including plant litter cover and type, and soil organic content), topography and climate (Jimenez *et al.*, 2006). Soil moisture characteristics are among the most important physical phenomena that affects the use of soils for agricultural purposes (Oyedele and Tijani2010).

Theoverall movement of water in the soil is influencedmajorly by the physical nature of the soil.It is noted that gravely and sandy soils, whichhave large pores, allow free movement of water without retaining much for plant use. In contrast, soils with highlevel of clay and organic matter or loamy soil, containinghumus or colloids have fine pores which allow increasedwater to rise through capillarity and high retention ofwater for plant use (Shittu and Amusan 2015). Soil moisture characteristics, enhances nutrient availability to the plants, helps keep the plant strive or rigid in shape, keeps the stems upright, and it also enhances photosynthesis (Li *et. al.*, 2004, Xu and Zhou 2011). Moisture stress has been established to negatively affect crop performance even when fertility status is high.

Changes in land use affects physical, chemical and biological characteristic of the soil (Macdonald *et al.*, 2000 and Shukla *et al.*, 2003).Chemeda*et. al.,*2017, reported that inappropriate land use management led to disturbance of soil nutrient status, indicating that the soil condition in the cultivated land is getting below the condition of soils under forest and grazing lands. Therefore, reducing intensity of cultivation, adopting integrated soil fertility management and application of organic fertilizers could maintain the existing soil condition and replenish degraded soil properties. In agricultural land use systems, mechanical disturbances, like tillage systems, can rapidly change the soil moisture characteristics (Lipiec*et al;* 2006).The destruction of the natural forest and pasture ecosystems and conversion tocropland can reduce soil productivity because of increased erosion, decline in fertility, changes inaeration and moisture content(Emadi*et. al.* 2008). It is therefore important to know the effect of various land use systems on soil moisture characteristics and nutrient transport within the soil matrix.

The effect of land use on moisture related properties of the upland soilsin the humid Tropical environment of the Niger Delta in Nigeria, have received very little attention. This current study therefore, is aimed at evaluating the effect of various land use types on moisture characteristics, as it affects retention and availability of moisture in a typical ultisol in a humid environment of the Niger Delta in Nigeria (Ojanuga*et.al.*1981).

II. Materials and Methods

The experiment was conducted at the Teaching and Research Farm of Rivers State University, Port Harcourt, Nigeria located at latitude $04^{0}46^{1}38.71^{11}$N and longitude $07^{0}01^{1}48.24^{11}$E, on an elevation of 16m above sea level. The study area has average rain fall of 3000mm-4500mm in a bimodal form and a peak in September and period of low precipitation in early august withmean annual temperature ranging from 22^{o}C – 33^{o}C(Weather Atlas 2018).The soil is typically sandy loam textured typic paleudult. (Ojanuga*et.al.*1981, Ayolagha and Ikiroma, 2013)

Soil Sampling

Six different land use sites were selected in the Rivers State University, Teaching and Research Farm. These includedsole maize (3years), planted forest (5years), mucunna plot (2years), plantain plantation (8years), orange orchard and the Telferia plots. Undisturbed soil samples were collected with cylindrical cores of known volume in triplicate, from three depth (0-5, 5-10 and 10-20cm) from the various land use types at the Teaching and Research Farm. The undisturbed samples were used to determine the soil bulk density, using the core method as described by Blake and Hartage (1986), and total porosity calculated from bulk density. The saturated hyadraullic conductivity was determined using the constant head permeameter method as described by Klute and Dirkson (1986). Specific surface of samples was calculated by a formular described by Santamarina*et. al.*, (2002).

Bulk soil samples were also collected at same depths, dried and passed through a 2mm mesh size sieve. This was used to determine particle size distribution, soil pH, organic matter content, total nitrogen.Particle size distribution was determined using the Bouyoucos hydrometer method as described by Gee and Bauder, (1986). Gravimetric moisture content (ϴm) was determined as a ratio of the mass of moisture to mass of oven-dried soils at a temperature of 105^{0}C, as described by DeAngelis (2007). The associated bulk density determined for each sample was used to convert the result to volume basis (ϴv).

The relationship between the volumetric moisture content and matric potential was done using the hanging water colum method (Vomicil 1965) At each matric potential, the samples were left to drain to equilibrium for24 hours and weight taken after equilibrium at that matric potential. The moisture content on a weight basis was also determined on equilibrium after 24 hours at each matric potential. These gravimetric moisture contents were then converted to volumetric contents and plotted against their associated matric potentials, to get the various soil moisture characteristic curves.

Data Analysis

The data collected was subjected to the one-way analysis of variance (ANOVA) using the Minitab 18 and means separated using the Turkey Pairwise Comparison at 95% confidence

III. Results and Discussion

The result of the particle size distribution of the soil of the study site as affected by land use is as shown on Table 4.1. The percentage sand fraction ranged between 78.6 to 84.6% with the planted forest having the 84.6% sand and Telferia plot having 15.4%. The high sand fraction could be attributed to the parent material dorminant in the area which is coastal plain sand since; the texture of the soil is highly influenced by parent material over time (Oguike and Mbagwu, 2009).The texture of soils were generally sandy loam to loamy sand. This result agrees with Onweremadu (2007) who observed similar textual characteristics on coastal plain soils in Owerri, south Easter Nigeria. Also the humid rainfall characteristics that promote eroding away of silt and particles may have contributed to the texture of soils in this area.

. **Table 4.1: Particle size distribution of soils under different land use**

LAND USE	% Clay	% Silt	% Sand	Textural Class
Maize Plot	11.4	8	80.6	Loamy sand
Mucuna	15.4	4	80.6	Sandy loam
Orange Orchard	13.4	6	80.6	Sandy loam
Planted Forest	13.4	2	84.6	Loamy sand
Telferia Plot	15.4	6	78.6	Sandy loam
Plantain Plantation	11.4	6	82.6	Loamy sand

The Bulk Densityvalues across the various land use types at the 0-5cm depth were in the order 1.65> 1.56 > 1.54 > 1.46 >1.45 > 1.43 gcm^{-3} forMucuna, Maize plot, Telferia Plot, Orange Orchard, Plantain Plantation, and Planted Forest, respectively (fig 4.1). These however, were not significantly different. The trend was generally the same at the 5-10 and 10-20cm depths. The bulk density values therefore did not vary significantly with depth for the 0-5 cm depth.

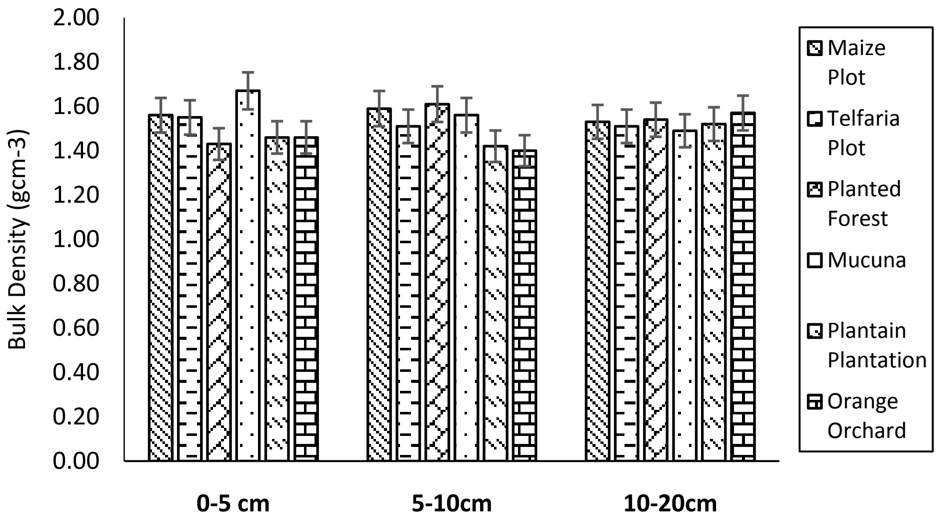

Fig. 4.1: Bulk Density of soils under different land use with Depth

The total porosity values of the various land uses is as shown on fig 4.2. Total porosity ranged between 37.9 to 45.1% at the 0-5 cm depth, 40.2 to 47.2% at the 5-10cm depth and 40.6% 43.6% at the 10-20cm depth. Generally, the higher the bulk density value, the lower the total porosity at all depths. At the 0-5cm depth the planted forest had the highest total porosity values of 46% while the Mucuna plot had the lowest value of 36.9%. However, the total porosity across all land use was not significantly different irrespective of depth. The planted forest with the highest total porosity at the 0-5cm depth also had the highest saturated hydraulic conductivity at the same depth. This agrees with previous findings that soil physical properties like porosity correlated positively with saturated hydraulic conductivity (Mbagwu and Mba 1998 and Egbuchua 2013).

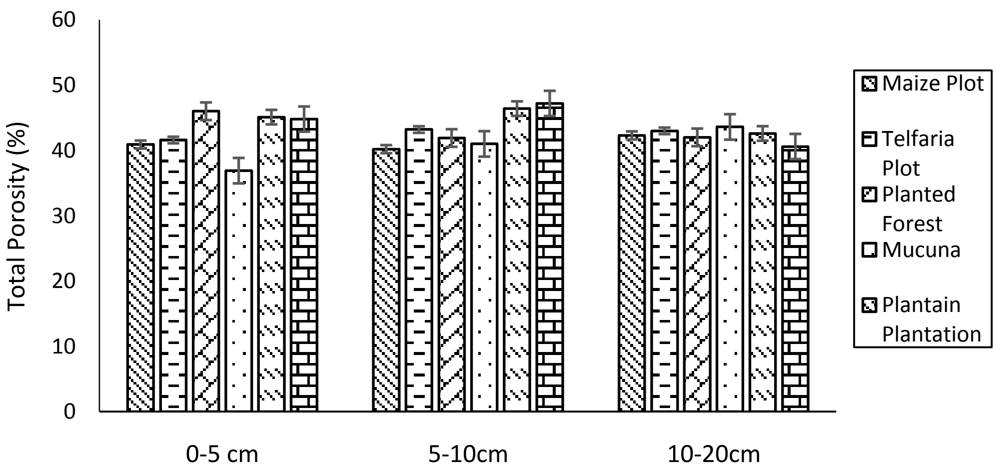

Fig.4.2: Total Porosity of soils under different land use with Depth

The saturated hydraulic conductivity was low to medium (Table 4.2). This is common with sandy soils significantly different with land use. The planted forest had the highest saturated hydraulic conductivity at all depth;9.62, 8.53 and 9.66cm^{-hr} for 0-5, 5-10 and 10-20cm depths respectively. The Telferia plot and orange orchard plots had the least saturated hydraulic conductivity values at all depths.Across all land use variation of saturated hydraulic conductivity with depth did not follow a particular trend. This could be attributed to the fact that saturated hydraulic conductivity is a function of porosity and pore size distribution.

Table 4.2: Saturated Hydraulic Conductivity (cmhr^{-1}) of soils under different land use with Depth

LAND USE	SOIL DEPTH (cm)		
	0-5	5-10	10-20
Maize plot	9.62^{a}	8.53^{a}	9.66^{a}
Mucuna	7.06^{ab}	5.93^{ab}	5.98^{ab}
Orange Orchard	6.48^{ab}	8.35^{ab}	6.23^{ab}
Planted Forest	5.76^{ab}	6.29^{ab}	5.86^{ab}
Telferia Plot	2.75^{b}	2.68^{b}	3.03^{b}
Plantain Plantation	2.68^{b}	3.05^{b}	2.89^{b}

* Means that do not share a letter are significantly different (Turkey method at 95% confidence level)

The relationship between matric suction and volumetric moisture content (soil moisture characteristics) as affected by land use is as shown on fig 4.3 and 4.4 for the 0-5 and 5-10cm depths. Generally volumetric moisture contented decreased with increase suction, across all land use and depths. At 10cm suction, the result showed a drop in moisture content. This may be as a result of the fact that the soil having very high percentage of sand and therefore macro pores emptied with little suction. Soils with these properties are reported to lack adsorption capacity for basic plant nutrient and water retention/Oguike and Mbagwu 2009).

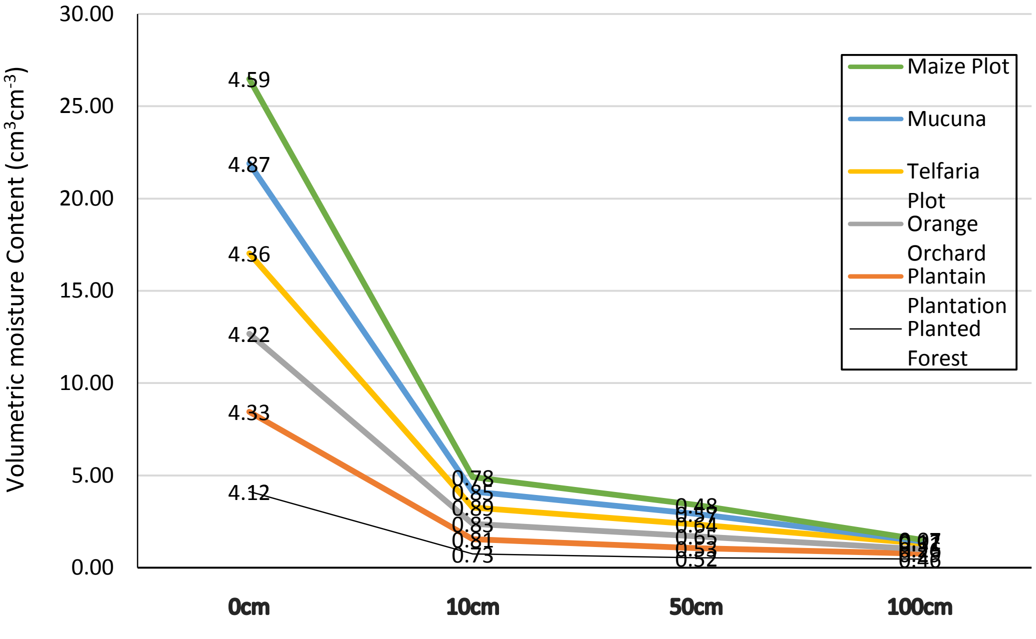

FIG.4.3 : Soil Moisture Characteristic Curve of the soils under different land use for the 0-5cm Depth

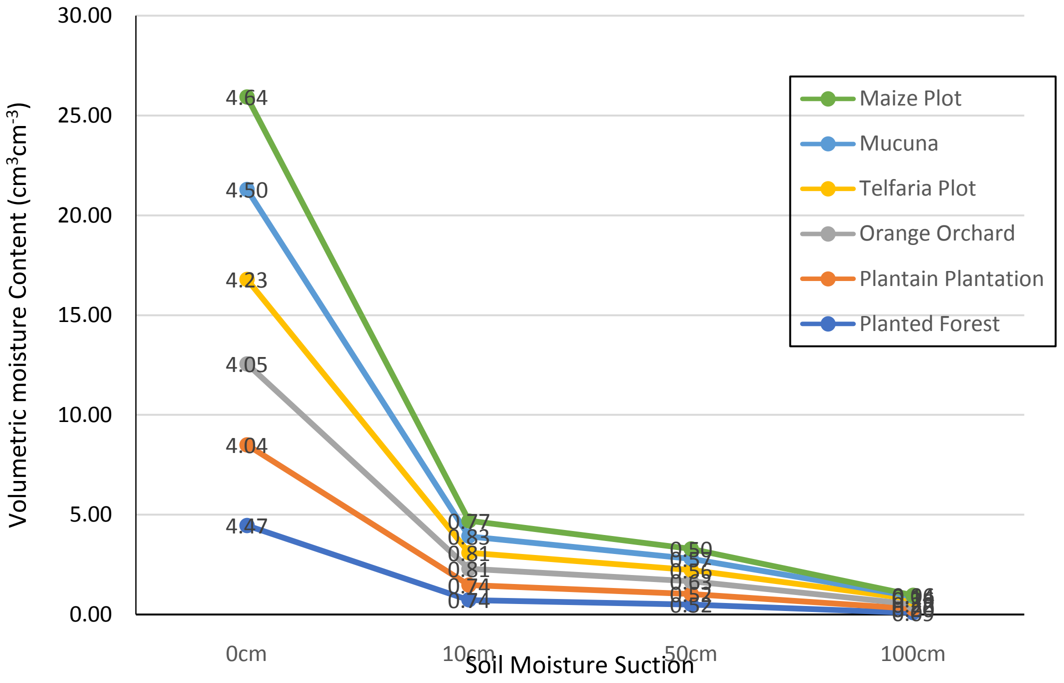

FIG. 4.4 : Soil Moisture Characteristic Curve of the soils under different land use for the 5- 10cm Depth

The maximum moisture retention (at 0cm suction) was in the order MU > MP >TP > PP > OO > PF at the 0-5cm depth and MP > MU > PF > TP > OO > PP at the 5-10cm depth (fig4.5 and 4.6). This did not follow a particular trend. They agrees with finding that moisture related properties varies with space and (Ahuja *et al* 1993). At field capacity (50cm) suction which is the maximum available water to crops, the moisture content was 0.65, 0.64, 0.57, 0.53, 0.52 and 0.48 cm^3cm^{-3} for Orange orchard, Telferia plot, Mucuna, Plantain plantation, Planted forest and Maize plot respectively. This suggests that this soil moisture retention is not just as a function of total porosity as suction increases.

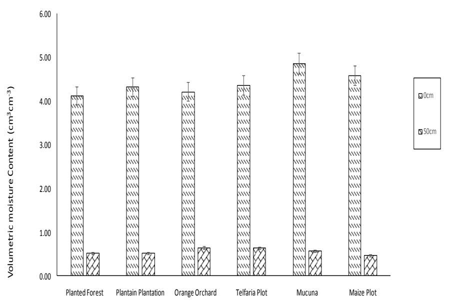

Fig. 4.3: Field Capacity of soils under different land use for 0-5cm Depth

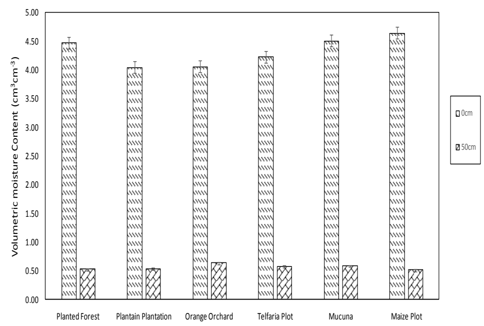

Fig. 4.4: Field Capacity of soils under different land use for 5-10cm Depth

The result of the pH of the soils is as shown on Table 4.3. The soils of the various land use are generally acid with Mucuna plot having the highest pH mean of 5.53 at (0-5) depth, 5.29 at (5-10), while the planted forest had the lowest pH mean of 4.62 at (0-5) and 5.00 at 5-10 depth. The continuous cultivation of these plots and also the low base saturation of this ultisol may have contributed to this. Nitrogen contents were very low. However, the soil from theorange orchard had the highest percentage nitrogen at 0-5 (0.0070), 5-10 (0.0084), followed by Mucunna, Maize plot, Plantain plantation, Planted forest and Telifera plot having the lowest total nitrogen at 0-5 (0.0035), at 5-10 (0.0021), respectively. This may have been as a result of the leguminous nature of Mucuna plant that fixes nitrogen to the soil and the continuous litter fall in the orange orchardResults also showed that the Orange orchard plot had the highest percentage organic carbon, followed by the plantain plantation, maize plot, planted forest, mucuna plot had the least.The organic matter content followed the same trend with the organic carbon. They were in the order orange orchard>plantain plantation>mucuna>planted forest>telferia>mucuna plot with values range between 1.28 to 2.62%. Dropping of leaves of plantain and oranges is these plots may have contributed to the organic matter content. The C/N ratio values were high ranging from 136.51 to 288.57 for the 0-5 cm depth and 96.10 to 480.95 for the 5-10 cm depth. The very low nitrogen content across the various land use may have contributed to this.

Table 4.3: Some Chemical Properties of the soils under different land use with Depth

LAND USE	%OC		% Total N		pH		%OM		C/N RATIO	
	0-5	5-10	0-5	5-10	0-5	5-10	0-5	5-10	0-5	5-10
Maize Plot	0.86	0.74	0.0063	0.0077	5.05	5.04	1.48	1.28	136.51	96.10
Telfaria Plot	1.01	1.01	0.0035	0.0021	4.60	5.01	1.74	1.74	288.57	480.95
Planted Forest	0.98	1.09	0.0035	0.0028	4.62	5.00	1.69	1.88	280.00	389.29
Mucuna	0.94	1.09	0.0077	0.0077	5.53	5.29	1.62	1.88	122.08	141.56
Plantain Plantation	1.52	1.33	0.0056	0.0049	5.13	4.85	2.62	2.29	271.43	271.43
Orange Orchard	1.59	1.52	0.0070	0.0084	5.30	4.77	2.74	2.62	227.14	180.95

1. Conclusion

The effect the various land use at the teaching and Research Farm on soil properties and soil water properties were investigated. Results showed that percentage sand across all land use was above 80% which is typical of coastal plain sand. The soil textures were sandy loam to loamy sand. The saturated hydraulic conductivity values were relatively medium to high. The sandy texture of the soils may have contributed to this. The total porosity values and saturated hydraulic conductivity were highest for the Telferia plot and Orange orchard. Bulk density was also lowest for the Planted forest and highest for the Mucuna. Soil moisture at the maximum retention at the maximum retention capacity was better related to total porosity. The trend was not the same for the field capacity; which is the maximum available moisture content for plants.

Results showed that the physical properties of the soil (structure) that were affected by land use also affected both the maximum retention capacity of the soil and more especially the field capacity. It is therefore recommended that the field capacity of the soil is a better information than the maximum retention capacity, with respect to water availability.

Land use types that degrade soil structure will negatively affect soil moisture characteristics.

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